GEOPHYSICAL SURVEYS FOR GROUND WATER EVALUATION NEAR WAIKOLOA VILLAGE, HI

FEB. 14, 1990

GEOPHYSICAL SURVEYS
FOR
GROUND WATER EVALUATION
NEAR WAIKOLOA VILLAGE, HAWAII

Prepared For:

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(Our Project #90003)

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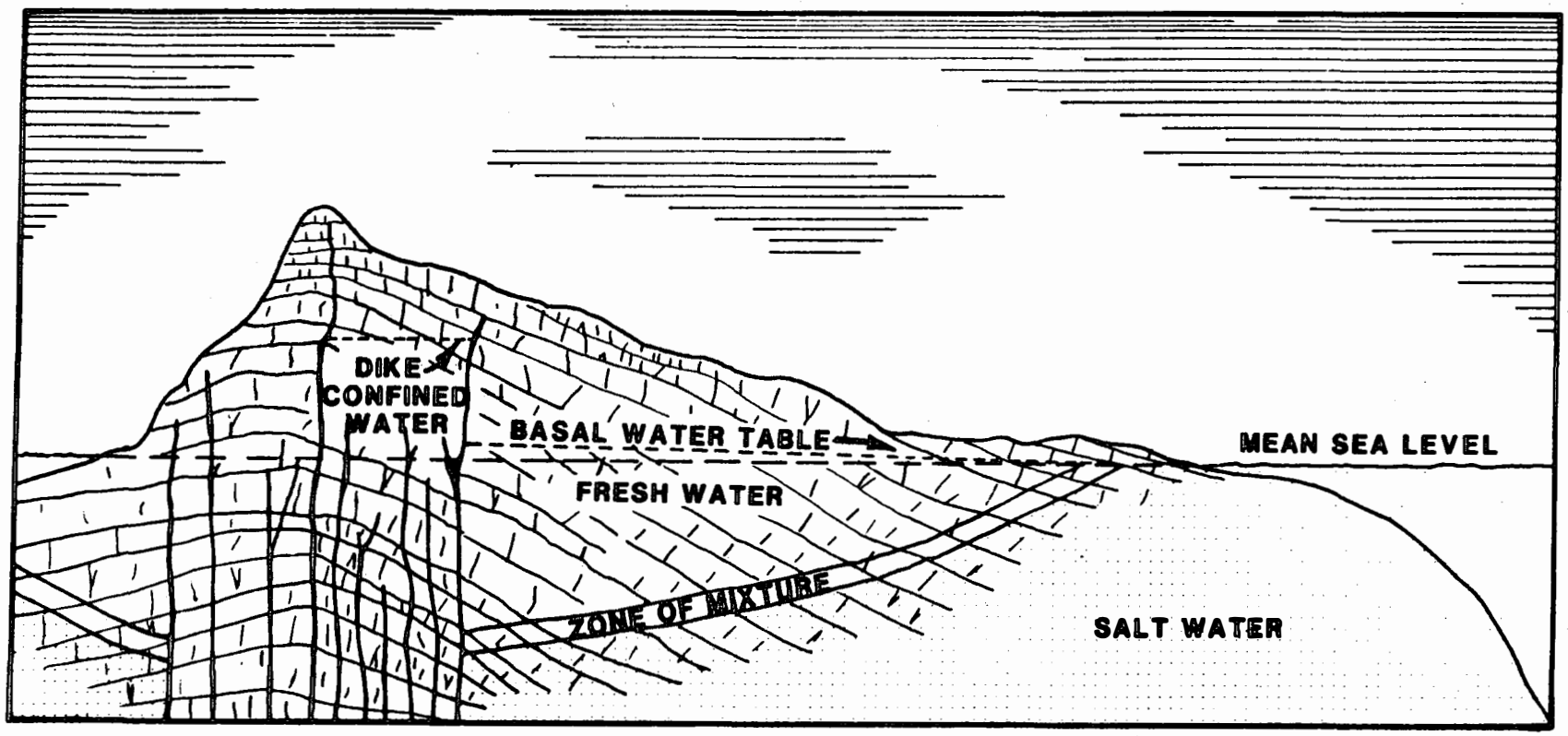
1.0 INTRODUCTION

This report contains the results of a time domain electromagnetic (TDEM) geophysical survey conducted to aid in the evaluation of fresh water resources near Waikoloa Village on the Island of Hawaii. The work was performed for Waikoloa Development Company (WDC) between January 15 and January 18, 1990.

The objective of the survey was to add to the data base (35 soundings) obtained in December 1988. In this survey eight additional soundings were acquired in the area of interest south of the existing Waikoloa well field. The concepts in the evaluation of the geophysical study can be understood from the hydrogeologic cross-section, typical of a volcanic island, shown in Figure 1-1. The volcanic rocks are generally highly permeable and rainfall rapidly infiltrates into the ground and migrates downward to the water table, and eventually discharges into the ocean. Fresh water in these settings is found in two environments.

1. Dike confined waters. Above the rift zone intrusive dikes originating from a magma source below can form ground water dams, and behind these natural dams significant quantities of ground water can be stored.

2. Basal fresh water. The high permeability of the volcanic rocks allows sea water to enter freely under the island, and a delicate balance is reached where a lens of fresh water floats on sea water. The Ghyben-Herzberg relation states that for every foot of fresh water head above sea level there will be 40 ft of fresh water below sea level. The basal water resource was the focus in the investigations for WDC. The geophysical surveys are used to provide optimum locations for well placement and information about optimum completion depths.



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SCHEMATIC HYDRO-GEOLOGIC CROSS SECTION

Waikoloa Development Co.

PROJECT NO.: 90003 FIGURE 1-1

2.0 LOGISTICS AND DATA ACQUISITION

A brief description of the fundamentals of TDEM is given in Appendix A. Briefly, the logistics of a TDEM measurement consist of:

1. Laying out a square loop of insulated wire. A generator placed on this loop is used to drive current pulses through this closed loop. The dimensions of square loops employed depend on the exploration depth requirements. The dimensions of the loops used for WDC were 1,000 ft by 1,000 ft.

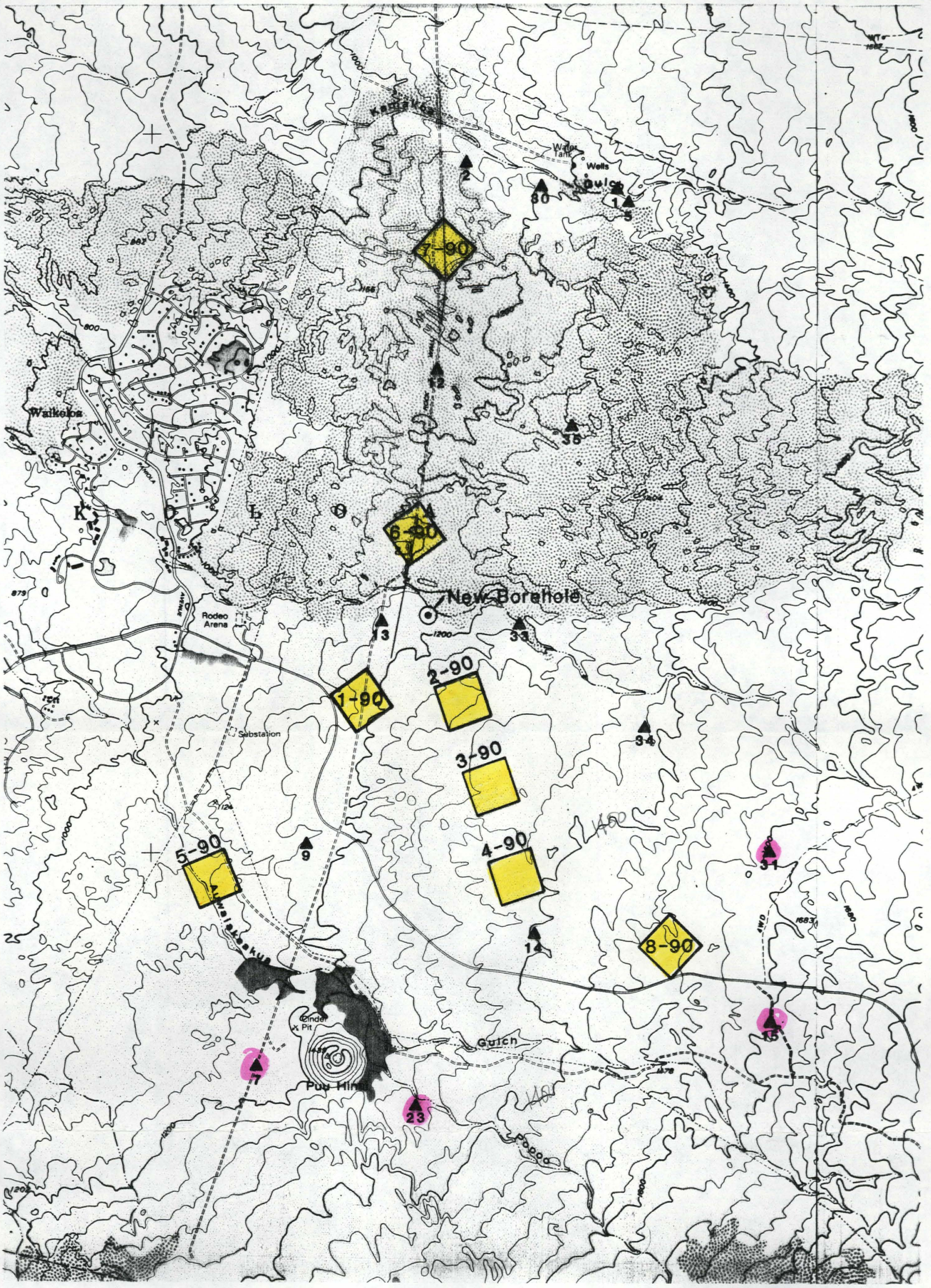
   Where possible, transmitter loop wires were positioned with at least one wire near roads and trails. The terrain in some of the measurement locations required off-road travel.

2. Making a measurement with a receiver in the center of the loop. The data acquired at each station was stored in the field on a solid state data logger and subsequently dumped to a computer at the end of each field day. The data acquired at each station usually consisted of measurements at several receiver gain settings and transmitter frequencies in order to assure data quality and to obtain data over the largest time range possible. Data quality was generally very good.

During three days of field work 8 stations (soundings) were completed. A daily log of field activity is given in Table 2-1. Figure 2-1 shows the location of the soundings conducted for Waikoloa Development Company.

Table 2-1. Daily log of field activities

Date (1990)	Activity
January 8	Mobilize to Kailua-Kona, Hawaii.
January 15	Meeting with Steve Hicks of Waikoloa Development Company. Measurement of sounding 1.
January 16	Measurement of soundings 2, 3 and 4.
January 17	Measurement of soundings 5, 6 and 7.
January 18	Measurement of sounding 8.
January 26-27	Demobilize from Kailua-Kona, HI to Golden, CO.



Puu Hinai Quadrangle
Island of Hawaii

BLACKHAWK GEOSCIENCES, INC.

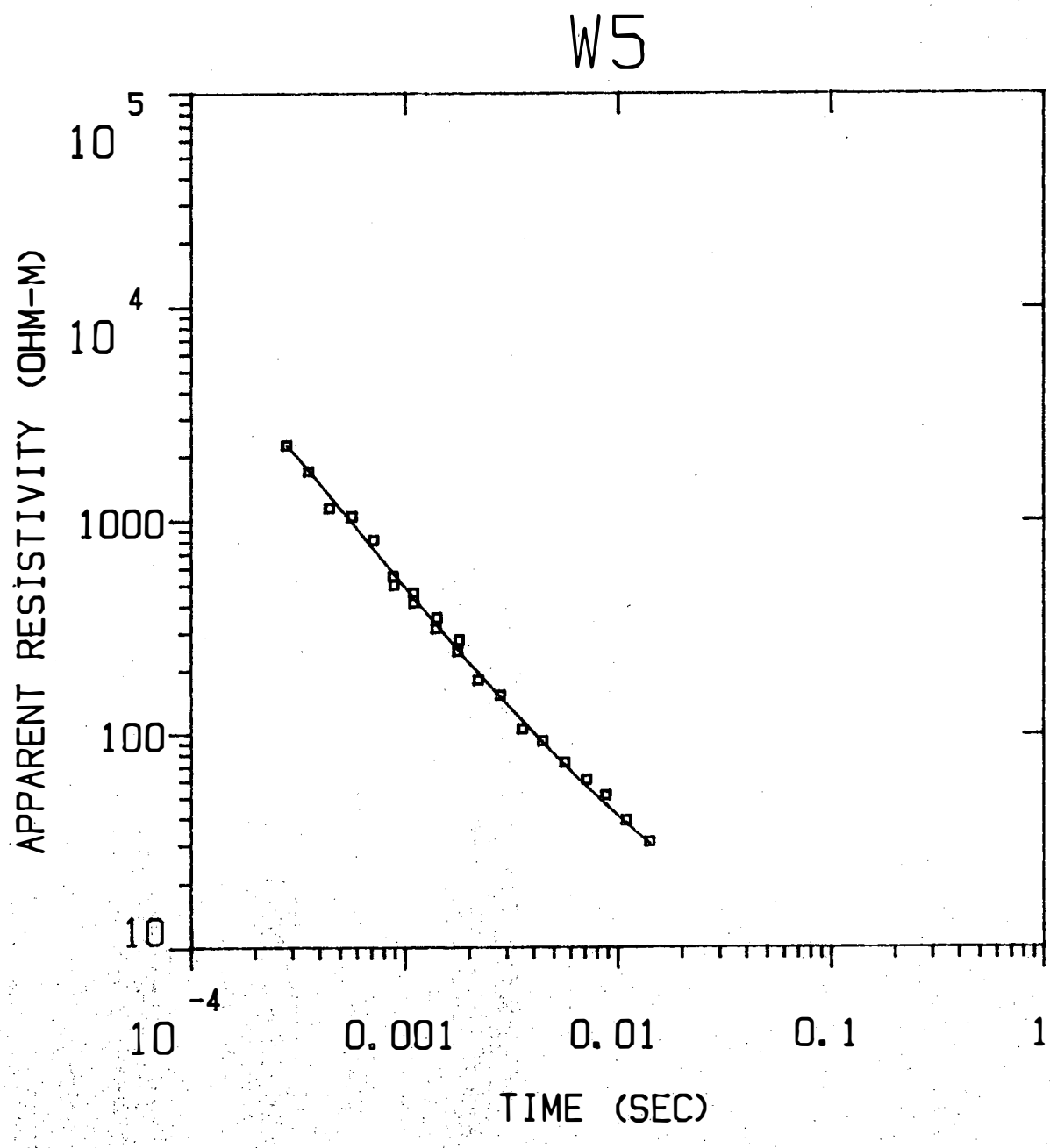
TIME DOMAIN EM SURVEY
LOCATION MAP
Waikoloa Development Company

PROJECT NO.: 90003 FIGURE 2-1

3.0 DATA PROCESSING

The objective of data processing is to derive from the TDEM measurements in the center of the loop the resistivity layering in the earth. The procedures of data processing are discussed in Appendix A. The results from data processing for each station are contained in Appendix B. A typical data set is given in Figures 3-1 and 3-2 for the station near the proposed golf course lake (loop #5). Figure 3-1 shows the measured data points (in terms of apparent resistivity) superimposed on a solid line. The solid line represents the computed behavior of the true resistivity layering shown on the right. It is evident that the computed behavior of the curve versus time matches the measured behavior well. Figure 3-2 lists in column 4 the error between measured and computed data in each time gate.

Figure 3-1 also shows that the resistivity layering in the upper 1,400 ft consists of two layers, - the first layer has a thickness of 399 m (1,309 ft) with a resistivity of 992 ohm-m, and the second layer has a resistivity of 2.8 ohm-m. All other stations collected during this survey were interpreted using a two-layer resistivity section.



MODEL:

992.
OHM-M

399. M

2.80
OHM-M

BLACKHAWK GEOSCIENCES, INC.

EXAMPLE
APPARENT RESISTIVITY CURVE
LOOP #5
Waikoloa Development Company

PROJECT NO.: 90003 **FIGURE 3-1**

% ERROR: 11.1
CALIBRATION: 1
OFFSET: 152. M
RAMP: 195.0
Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		326.7	1072.0		
991.63	399.0	-72.3	-237.2	0.4	0.4
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	2.80E-04	2.24E+03	2.26E+03	-0.600	
2	3.55E-04	1.69E+03	1.73E+03	-2.560	
3	4.43E-04	1.14E+03	1.31E+03	-13.325	
4	5.64E-04	1.04E+03	9.81E+02	6.122	
5	7.13E-04	8.08E+02	7.40E+02	9.267	
6	8.81E-04	5.50E+02	5.72E+02	-3.712	
7	8.90E-04	5.00E+02	5.65E+02	-11.423	
8	1.10E-03	4.60E+02	4.39E+02	4.794	
9	1.10E-03	4.15E+02	4.37E+02	-5.195	
10	1.40E-03	3.15E+02	3.30E+02	-4.748	
11	1.41E-03	3.53E+02	3.27E+02	7.767	
12	1.77E-03	2.46E+02	2.51E+02	-2.082	
13	1.80E-03	2.78E+02	2.47E+02	12.569	
14	2.20E-03	1.80E+02	1.96E+02	-7.965	
15	2.80E-03	1.53E+02	1.50E+02	1.691	
16	3.55E-03	1.05E+02	1.16E+02	-8.880	
17	4.43E-03	9.25E+01	9.18E+01	0.799	
18	5.64E-03	7.32E+01	7.16E+01	2.318	
19	7.13E-03	6.08E+01	5.67E+01	7.102	
20	8.81E-03	5.13E+01	4.64E+01	10.455	
21	1.10E-02	3.91E+01	3.79E+01	3.185	
22	1.41E-02	3.10E+01	3.05E+01	1.782	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 22 DATA POINTS, RAMP: 195.0 MICROSEC, DATA: W5
1701 002N 005N Z OPR XTL H 6 8+100
Ch.21 = 0.195 Ch.22 = 0.089 Ch.23 = 19 Ch.24 =
RMS LOG ERROR: 4.57E-02, ANTILOG YIELDS 11.1059 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.05
F 2 0.00 0.00
T 1 0.02 0.00 0.98
P 1 F 2 T 1

BLACKHAWK GEOSCIENCES, INC.
INTERPRETATION RESULTS
LOOP #5
Waikoloa Development Company
PROJECT NO.: 90003 FIGURE 3-2

4.0 INTERPRETATION RESULTS

4.1 GENERAL

The objective of the geophysical survey at Waikoloa is not to obtain the resistivity layering of the subsurface, but to infer from the resistivity information about the depth to salt water and the thickness of the basal fresh water lens. The translation of resistivity layering into hydrogeologic information is generally accomplished in two ways:

1. Using available knowledge about the relation between resistivity values and hydrogeology. For example, in the volcanic rocks of Hawaii rocks saturated with salt water will have resistivities less than 5 ohm-m. On the other hand, dry volcanic rocks will have very high resistivities (typically much greater than 100 ohm-m).

2. Calibrating the geophysical interpretation at a well. In this case calibration was derived from the survey performed in December 1988. From the survey in 1988 in the Waikoloa area 2.8 ohm-m was interpreted to represent the resistivity of the saline water saturated volcanic zone. The resistivity of the basal saline water was fixed at this value for all interpretations. The validity of using this resistivity value for saline water saturated volcanics was confirmed by a recent well drilled in 1988 between soundings 13 and 33 (Fig. 2-1). In this well fresh water was encountered at about 8 ft above sea level in close agreement with the 1988 survey results.

4.2 INTERPRETATION OF SOUNDINGS

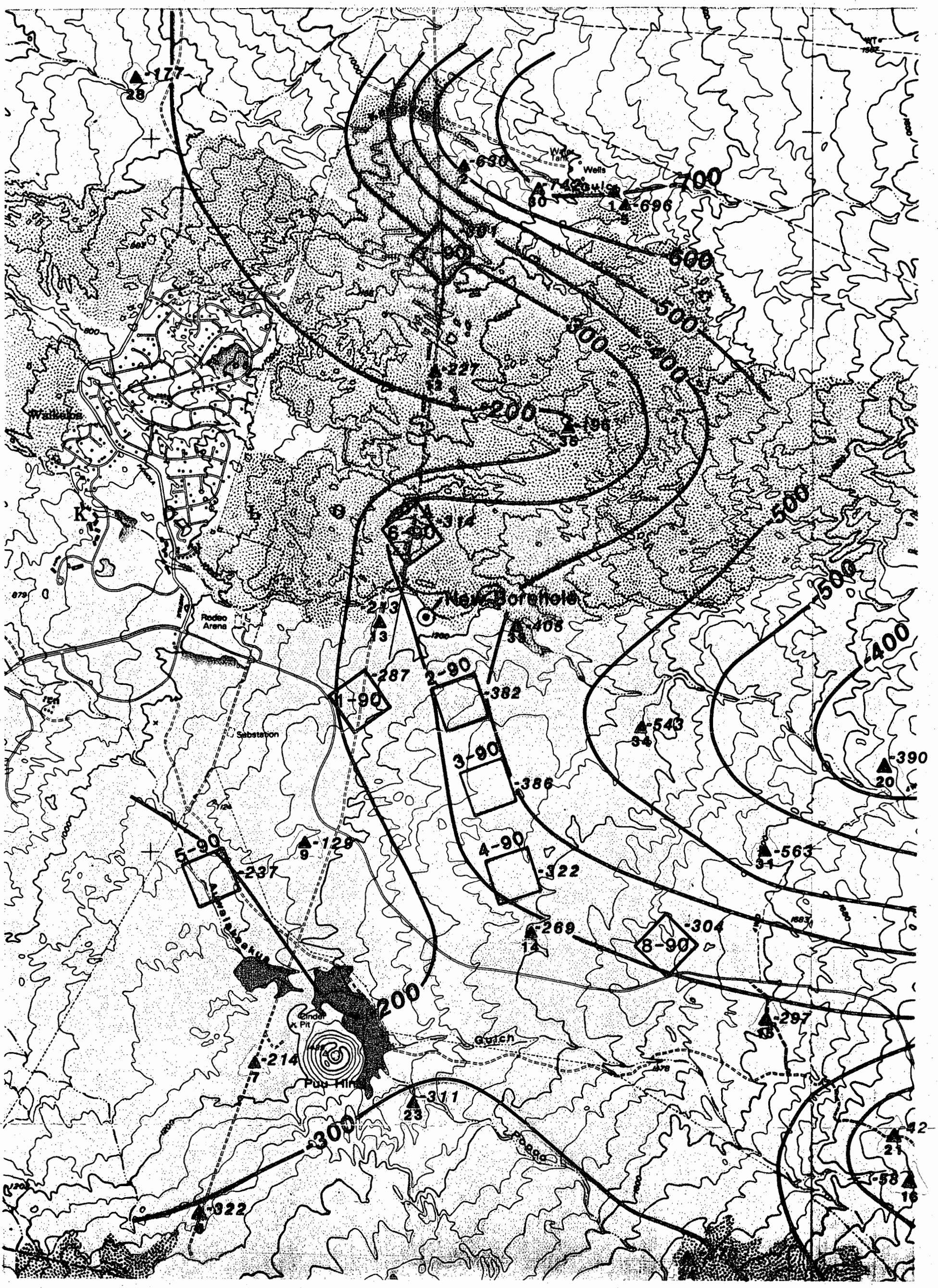
The location of the soundings conducted for Waikoloa Development Company are shown in Figure 2-1. From the interpreted depth to the saline layer the amount of head and thickness of the fresh/brackish water lens can be calculated using the Ghyben-Herzberg relationship. This relationship states that for every foot of fresh water above sea level there will be forty feet of fresh water below sea level. Generally, it is difficult to discriminate between fresh water saturated volcanics and brackish water (less than 1,000 ppm chlorides) saturated volcanics by resistivity interpretations. The reason is that in addition to salinity, changes in porosity and lithology also influence formation resistivity, particularly at low values of chloride concentration. For this reason, in the following interpretations the term "fresh/brackish" is used to refer to the water overlying the basal sea water.

The results are summarized in Table 4-1.

Table 4-1. Hydrogeologic information derived from TDEM soundings

Sounding #	Surface Elevation (ft)	Elevation of Conductive Layer	Head of Fresh/ Brackish Water above Sea Level (water table) (ft)	Thickness of Fresh/ Brackish Water Lens (ft)
1	1200	-287	7.2	294
2	1260	-382	9.5	391
3	1320	-405	10.1	415
4	1380	-322	8	330
5 HIGHLANDS G.C.	1072	-237	5.9	243
6 NORTH OF WAI. WELL Nº2	1200	-314	7.9	322
7 HEBR EX. WELL FIELD	1110	-301	7.5	308
8 WAIKOLOA RD	1520	-293	7.3	300

The additional soundings performed on this survey were used to produce a revised contour map of depth to saline water. The revised contour map is shown in Figure 4-1. There is good agreement between the interpretations of the December 1988 survey and the additional data collected in the January 1990 survey. The additional data confirmed the steep gradient in depth to saline water near the Waikoloa well field (between soundings 7-90 and soundings 2, 30 and 1 taken in 1988). The additional soundings taken south of the new borehole (1-90 through 4-90) confirm the trends observed in the 1988 data, and shift the contours of depth to saline water slightly to the west as compared to the 1988 contour map.



Puu Hinai Quadrangle
Island of Hawaii

BLACKHAWK GEOSCIENCES, INC.

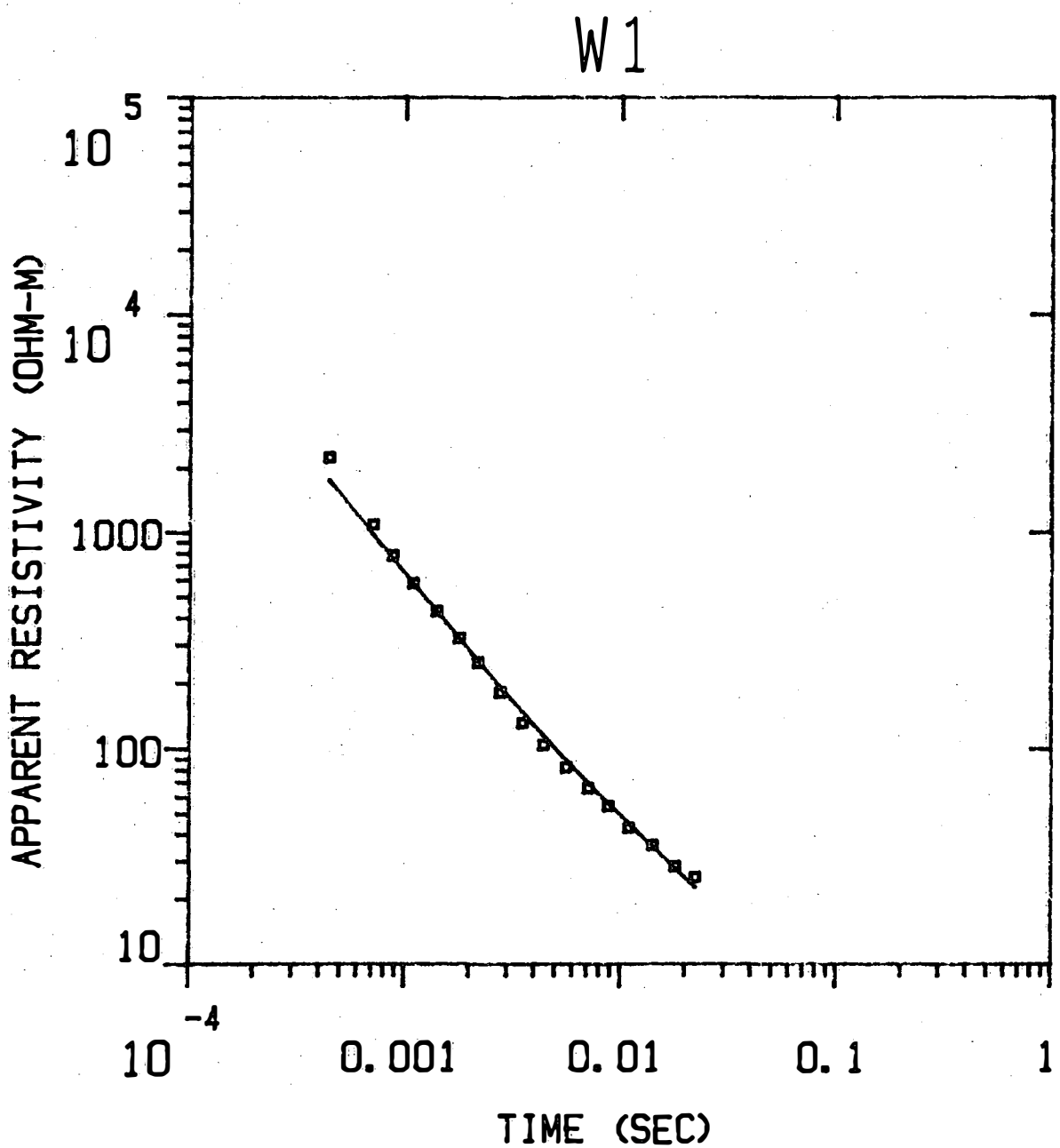
TIME DOMAIN EM SURVEY
CONTOURS OF ELEVATION
OF 2.8 OHM-M BOUNDARY
Waikoloa Development Company

PROJECT NO.: 90003 FIGURE 4-1

5.0 CONCLUSIONS

Eight TDEM soundings were acquired during the survey to add to the existing data base (35 soundings) acquired during 1988. The additional data was used to revise the contour map of elevation of saline water in the area south of the Waikoloa well field and south of the new borehole (Fig. 4-1).

The newly acquired data show good agreement with the data set taken in 1988. The revised contour map confirms the steep gradient in depth to saline water near the Waikoloa well field. In the area south of the new borehole the additional data causes the contours of depth to saline water to shift very slightly toward the west. The sounding near the proposed golf course pond (5-90) shows an elevation of -237 ft to saline water, or an estimated head elevation of 5.9 ft.



MODEL:

6497.
OHM-M

453. M

2.80
OHM-M

% ERROR: 13.4
CALIBRATION: 1
OFFSET: 152. M
SYSTEM: NONE
Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		365.8	1200.0		
6497.16	453.3	-87.5	-287.1	0.1	0.1
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	2.21E+03	1.76E+03	25.823	
2	7.13E-04	1.09E+03	9.78E+02	11.076	
3	8.81E-04	7.78E+02	7.55E+02	3.097	
4	1.10E-03	5.78E+02	5.80E+02	-0.303	
5	1.41E-03	4.28E+02	4.29E+02	-0.303	
6	1.80E-03	3.21E+02	3.22E+02	-0.514	
7	2.20E-03	2.49E+02	2.55E+02	-2.083	
8	2.80E-03	1.82E+02	1.93E+02	-5.809	
9	3.55E-03	1.31E+02	1.48E+02	-11.125	
10	4.43E-03	1.04E+02	1.16E+02	-10.081	
11	5.64E-03	8.21E+01	8.91E+01	-7.878	
12	7.13E-03	6.56E+01	6.97E+01	-5.836	
13	8.81E-03	5.42E+01	5.60E+01	-3.263	
14	1.10E-02	4.28E+01	4.50E+01	-4.801	
15	1.41E-02	3.55E+01	3.51E+01	1.334	
16	1.80E-02	2.83E+01	2.77E+01	2.218	
17	2.22E-02	2.51E+01	2.27E+01	10.937	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 17 DATA POINTS, SYSTEM: NONE DATA: W1
LOOP CENTER 750 FEET SOUTH OF FIRST GATE

RMS LOG ERROR: 5.46E-02, ANTILOG YIELDS 13.3893 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

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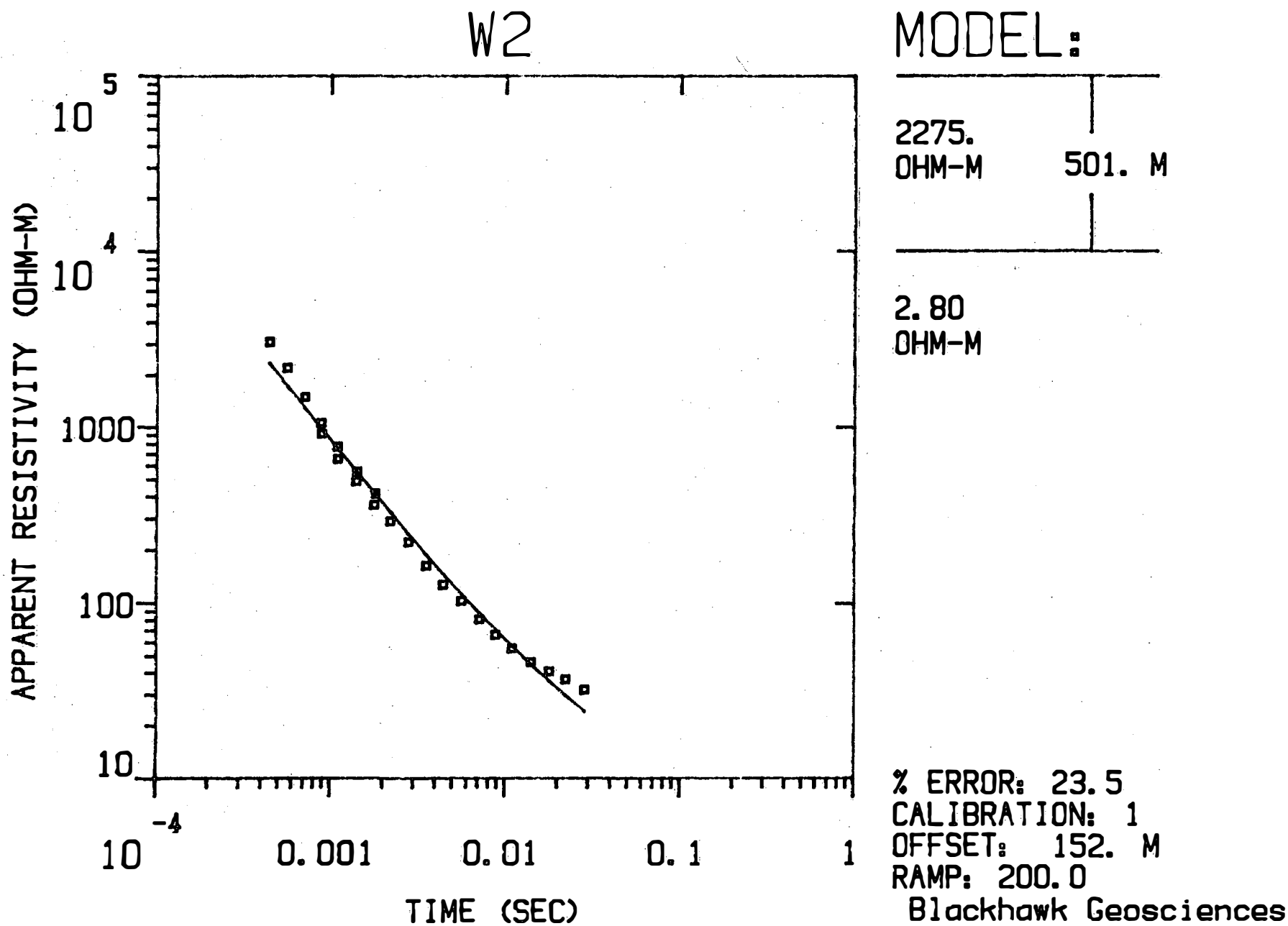
F 2	0.00	0.00	
T 1	0.00	0.00	1.00
	P 1	F 2	T 1


W2
MODEL:
2275.
OHM-M
501. M
2.80
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-4
0.001
0.01
0.1
1
TIME (SEC)
% ERROR: 23.5
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
Blackhawk Geosciences

W2

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		384.0	1260.0		
2274.72	500.6	-116.6	-382.4	0.2	0.2
2.80					

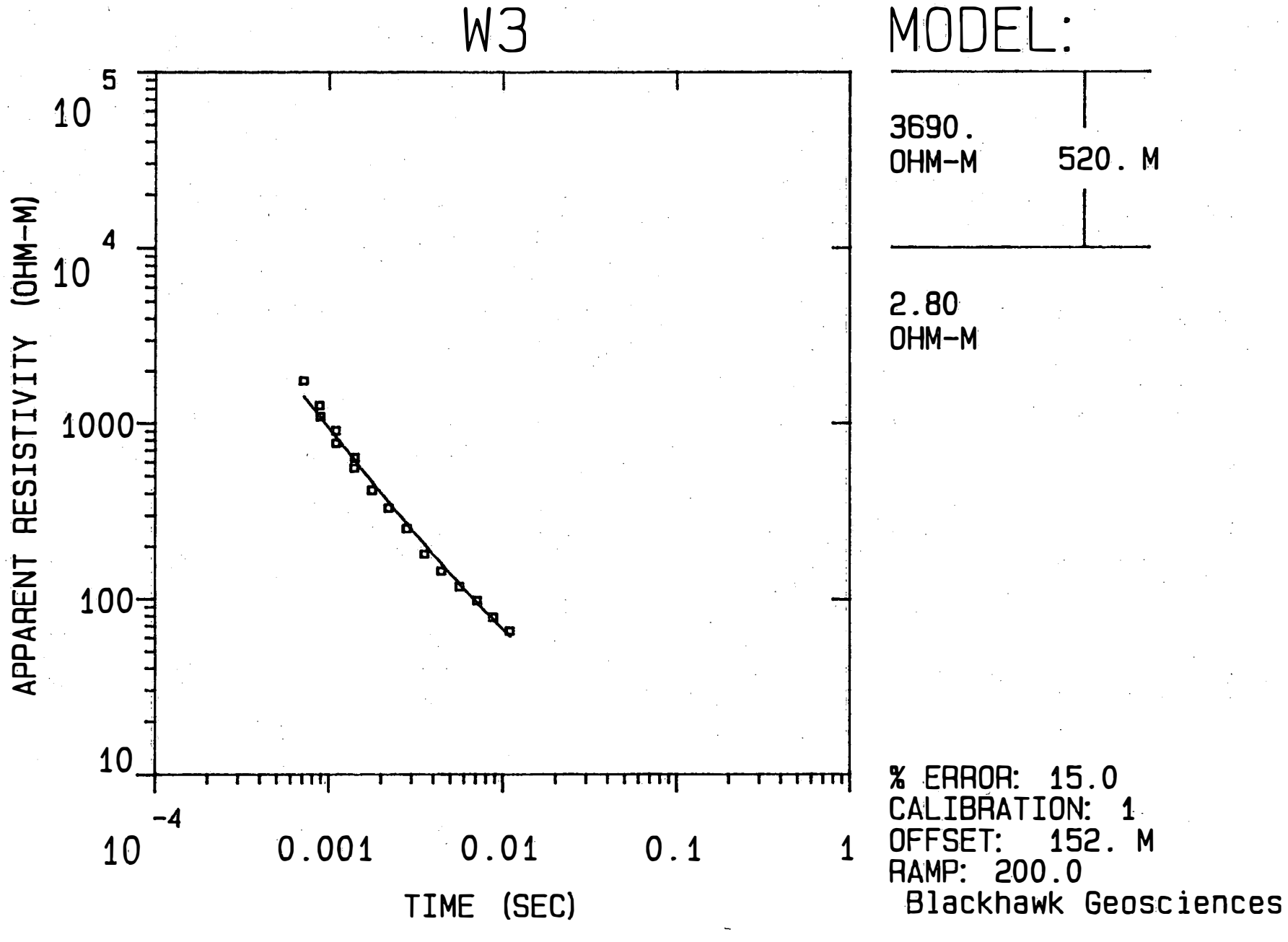
	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	3.07E+03	2.34E+03	30.933	
2	5.64E-04	2.19E+03	1.73E+03	26.850	
3	7.13E-04	1.49E+03	1.28E+03	16.022	
4	8.81E-04	1.05E+03	9.84E+02	7.090	
5	8.90E-04	9.15E+02	9.72E+02	-5.893	
6	1.10E-03	7.69E+02	7.54E+02	2.045	
7	1.10E-03	6.54E+02	7.50E+02	-12.825	
8	1.40E-03	4.87E+02	5.58E+02	-12.715	
9	1.41E-03	5.56E+02	5.52E+02	0.579	
10	1.77E-03	3.58E+02	4.21E+02	-15.110	
11	1.80E-03	4.15E+02	4.14E+02	0.286	
12	2.20E-03	2.89E+02	3.26E+02	-11.203	
13	2.80E-03	2.21E+02	2.46E+02	-10.159	
14	3.55E-03	1.63E+02	1.88E+02	-13.362	
15	4.43E-03	1.27E+02	1.47E+02	-13.277	
16	5.64E-03	1.03E+02	1.13E+02	-8.666	
17	7.13E-03	8.08E+01	8.80E+01	-8.201	
18	8.81E-03	6.59E+01	7.07E+01	-6.778	
19	1.10E-02	5.51E+01	5.70E+01	-3.284	
20	1.41E-02	4.58E+01	4.46E+01	2.724	
21	1.80E-02	4.06E+01	3.57E+01	13.697	
22	2.22E-02	3.65E+01	2.96E+01	23.460	
23	2.85E-02	3.18E+01	2.39E+01	33.037	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 23 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: W2
1601 002N 002N Z OPR XTL H 6 8+100
Ch.21 = 0.2 Ch.22 = 0.089 Ch.23 = 19 Ch.24 = 92
RMS LOG ERROR: 9.17E-02, ANTILOG YIELDS 23.5004 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.00		
F 2	0.00	0.00	
T 1	0.01	0.00	0.98
	P 1	F 2	T 1



MODEL:

3690.
OHM-M

520. M

2.80
OHM-M

% ERROR: 15.0
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0

Blackhawk Geosciences

MODEL: 2 LAYERS

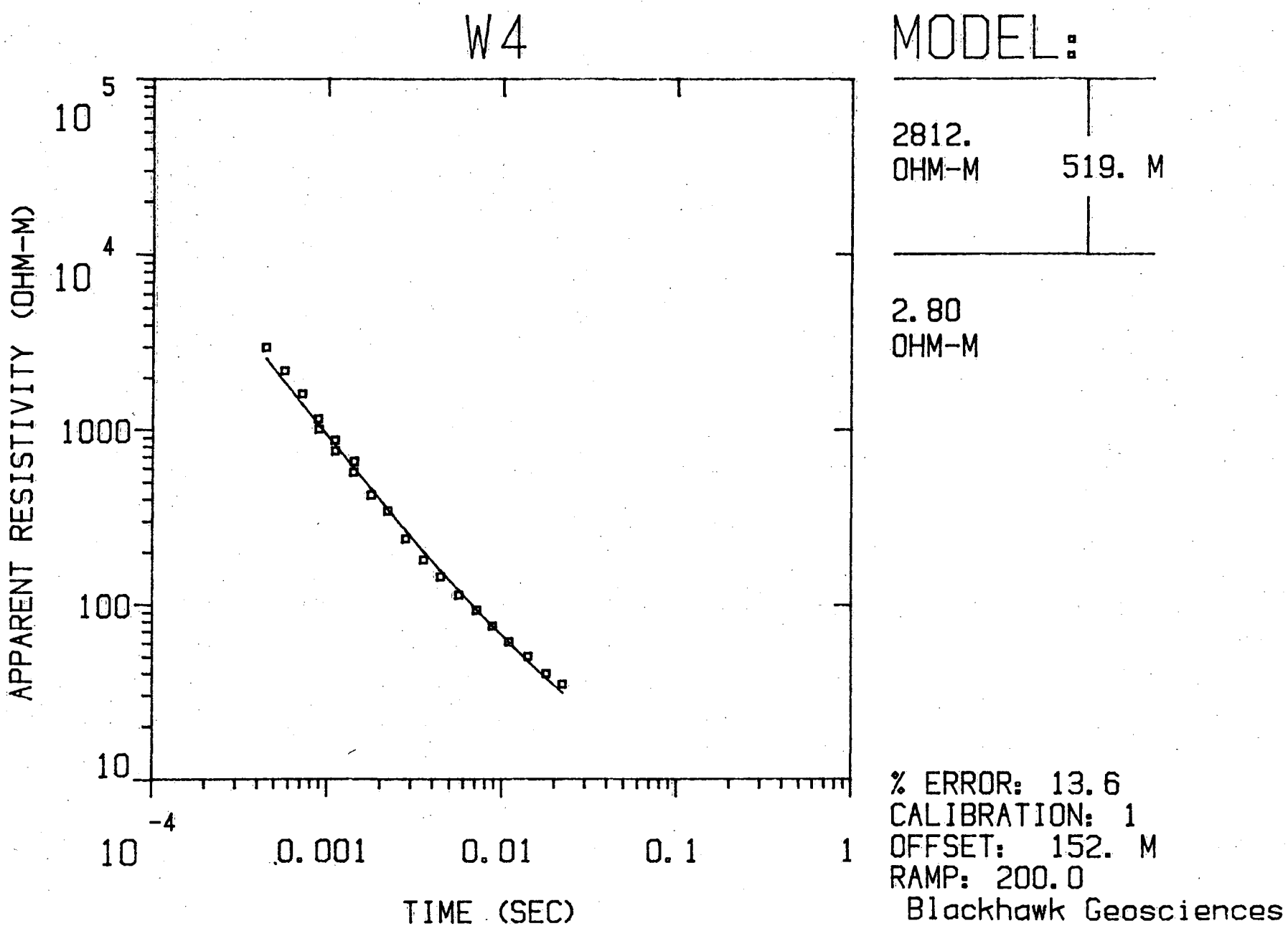
RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		402.3	1320.0		
3690.27	520.1	-117.8	-386.4	0.1	0.1
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	7.13E-04	1.74E+03	1.42E+03	22.204	
2	8.81E-04	1.26E+03	1.09E+03	15.766	
3	8.90E-04	1.09E+03	1.07E+03	1.563	
4	1.10E-03	9.03E+02	8.29E+02	8.919	
5	1.10E-03	7.66E+02	8.25E+02	-7.210	
6	1.40E-03	5.55E+02	6.13E+02	-9.452	
7	1.41E-03	6.33E+02	6.07E+02	4.182	
8	1.77E-03	4.16E+02	4.61E+02	-9.835	
9	2.20E-03	3.30E+02	3.56E+02	-7.324	
10	2.80E-03	2.52E+02	2.68E+02	-5.747	
11	3.55E-03	1.81E+02	2.04E+02	-11.315	
12	4.48E-03	1.44E+02	1.59E+02	-9.032	
13	5.64E-03	1.18E+02	1.22E+02	-3.078	
14	7.13E-03	9.79E+01	9.47E+01	3.395	
15	8.81E-03	7.82E+01	7.57E+01	3.357	
16	1.10E-02	6.52E+01	6.06E+01	7.615	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 16 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: W3
1601 002M 003N Z OPR XTL H 6 8+100
Ch.21 = 0.2 Ch.22 = 0.089 Ch.23 = 19 Ch.24 = 92
RMS LOG ERROR: 6.06E-02, ANTILOG YIELDS 14.9634 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.95
F 2 0.00 0.00
T 1 0.00 0.00 1.00
P 1 F 2 T 1


W4
MODEL:
2812.
OHM-M
519. M
2.80
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-4
0.001
0.01
0.1
1
TIME (SEC)
% ERROR: 13.6
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
Blackhawk Geosciences

MODEL: 2 LAYERS

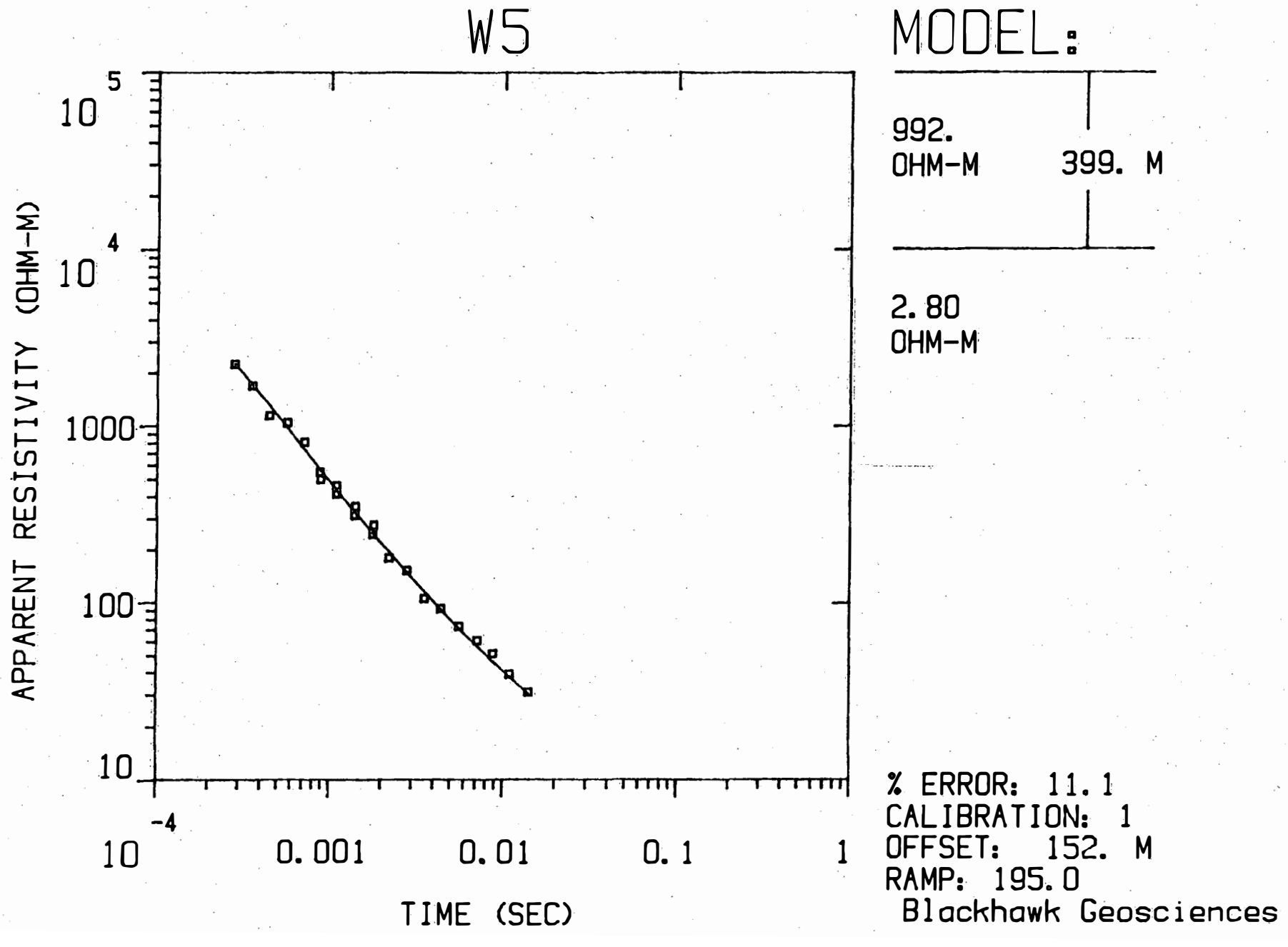
RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		420.6	1380.0		
2812.03	518.7	-98.1	-321.8	0.2	0.2
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	2.97E+03	2.58E+03	15.045	
2	5.64E-04	2.18E+03	1.89E+03	15.297	
3	7.13E-04	1.60E+03	1.40E+03	14.245	
4	8.81E-04	1.15E+03	1.08E+03	6.553	
5	8.90E-04	1.00E+03	1.06E+03	-5.880	
6	1.10E-03	8.65E+02	8.20E+02	5.573	
7	1.10E-03	7.52E+02	8.16E+02	-7.866	
8	1.40E-03	5.67E+02	6.07E+02	-6.537	
9	1.41E-03	6.56E+02	6.01E+02	9.153	
10	1.77E-03	4.20E+02	4.57E+02	-8.222	
11	2.20E-03	3.43E+02	3.53E+02	-2.835	
12	2.80E-03	2.38E+02	2.66E+02	-10.460	
13	3.55E-03	1.81E+02	2.02E+02	-10.687	
14	4.43E-03	1.44E+02	1.58E+02	-8.435	
15	5.64E-03	1.13E+02	1.21E+02	-6.508	
16	7.13E-03	9.28E+01	9.41E+01	-1.348	
17	8.81E-03	7.52E+01	7.56E+01	-0.485	
18	1.10E-02	6.10E+01	6.05E+01	0.771	
19	1.41E-02	5.02E+01	4.72E+01	6.405	
20	1.80E-02	3.98E+01	3.76E+01	5.816	
21	2.22E-02	3.45E+01	3.09E+01	11.889	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 21 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: W4
1601 002N 004N Z OPR XTL H 6 8+100
Ch.21 = 0.2 Ch.22 = 0.089 Ch.23 = 19 Ch.24 = 92
RMS LOG ERROR: 5.55E-02, ANTILOG YIELDS 13.6419 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.20
F 2 0.00 0.00
T 1 0.01 0.00 1.00
P 1 F 2 T 1


W5
MODEL:
992.
OHM-M
399. M
2.80
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-4
0.001
0.01
0.1
1
TIME (SEC)
% ERROR: 11.1
CALIBRATION: 1
OFFSET: 152. M
RAMP: 195.0
Blackhawk Geosciences

MODEL : 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		326.7	1072.0		
991.63	399.0	-72.3	-237.2	0.4	0.4
2.80					

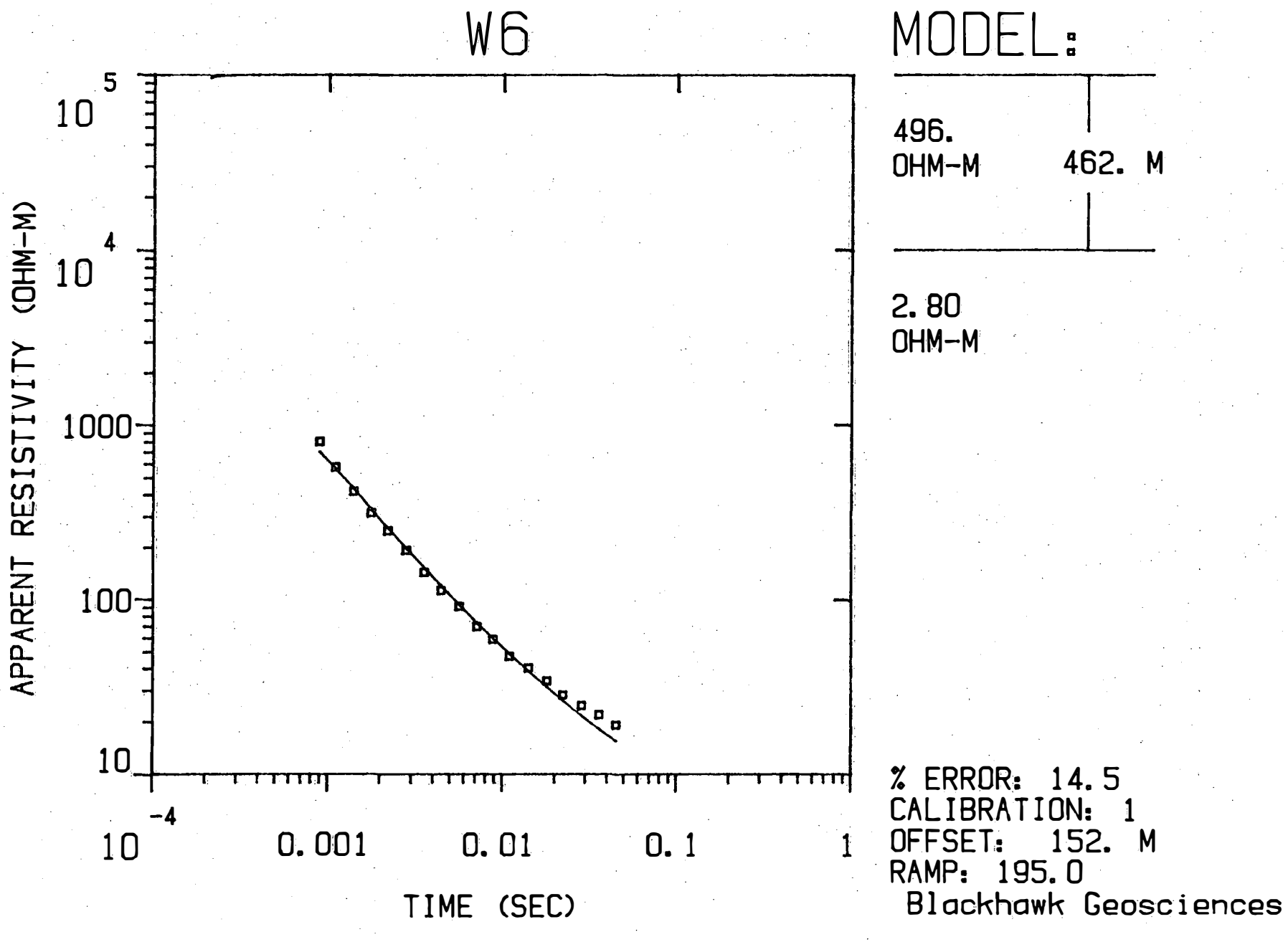
	TIMES	DATA	CALC	% ERROR	STD ERR
1	2.80E-04	2.24E+03	2.26E+03	-0.600	
2	3.55E-04	1.69E+03	1.73E+03	-2.560	
3	4.43E-04	1.14E+03	1.31E+03	-13.325	
4	5.64E-04	1.04E+03	9.81E+02	6.122	
5	7.13E-04	8.08E+02	7.40E+02	9.267	
6	8.81E-04	5.50E+02	5.72E+02	-3.712	
7	8.90E-04	5.00E+02	5.65E+02	-11.423	
8	1.10E-03	4.60E+02	4.39E+02	4.794	
9	1.10E-03	4.15E+02	4.37E+02	-5.195	
10	1.40E-03	3.15E+02	3.30E+02	-4.748	
11	1.41E-03	3.53E+02	3.27E+02	7.767	
12	1.77E-03	2.46E+02	2.51E+02	-2.082	
13	1.80E-03	2.78E+02	2.47E+02	12.569	
14	2.20E-03	1.80E+02	1.96E+02	-7.965	
15	2.80E-03	1.53E+02	1.50E+02	1.691	
16	3.55E-03	1.05E+02	1.16E+02	-8.880	
17	4.43E-03	9.25E+01	9.18E+01	0.799	
18	5.64E-03	7.32E+01	7.16E+01	2.318	
19	7.13E-03	6.08E+01	5.67E+01	7.102	
20	8.81E-03	5.13E+01	4.64E+01	10.455	
21	1.10E-02	3.91E+01	3.79E+01	3.185	
22	1.41E-02	3.10E+01	3.05E+01	1.782	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 22 DATA POINTS, RAMP: 195.0 MICROSEC, DATA: W5
1701 002N 005N Z OPR XTL H 6 8+100
Ch.21 = 0.195 Ch.22 = 0.089 Ch.23 = 19 Ch.24 =
RMS LOG ERROR: 4.57E-02, ANTILOG YIELDS 11.1059 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.05		
F 2	0.00	0.00	
T 1	0.02	0.00	0.98
	P 1	F 2	T 1


W6
MODEL:
496.
OHM-M
462. M
2.80
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-4
0.001
0.01
0.1
1
TIME (SEC)
% ERROR: 14.5
CALIBRATION: 1
OFFSET: 152. M
RAMP: 195.0
Blackhawk Geosciences

MODEL: 2 LAYERS

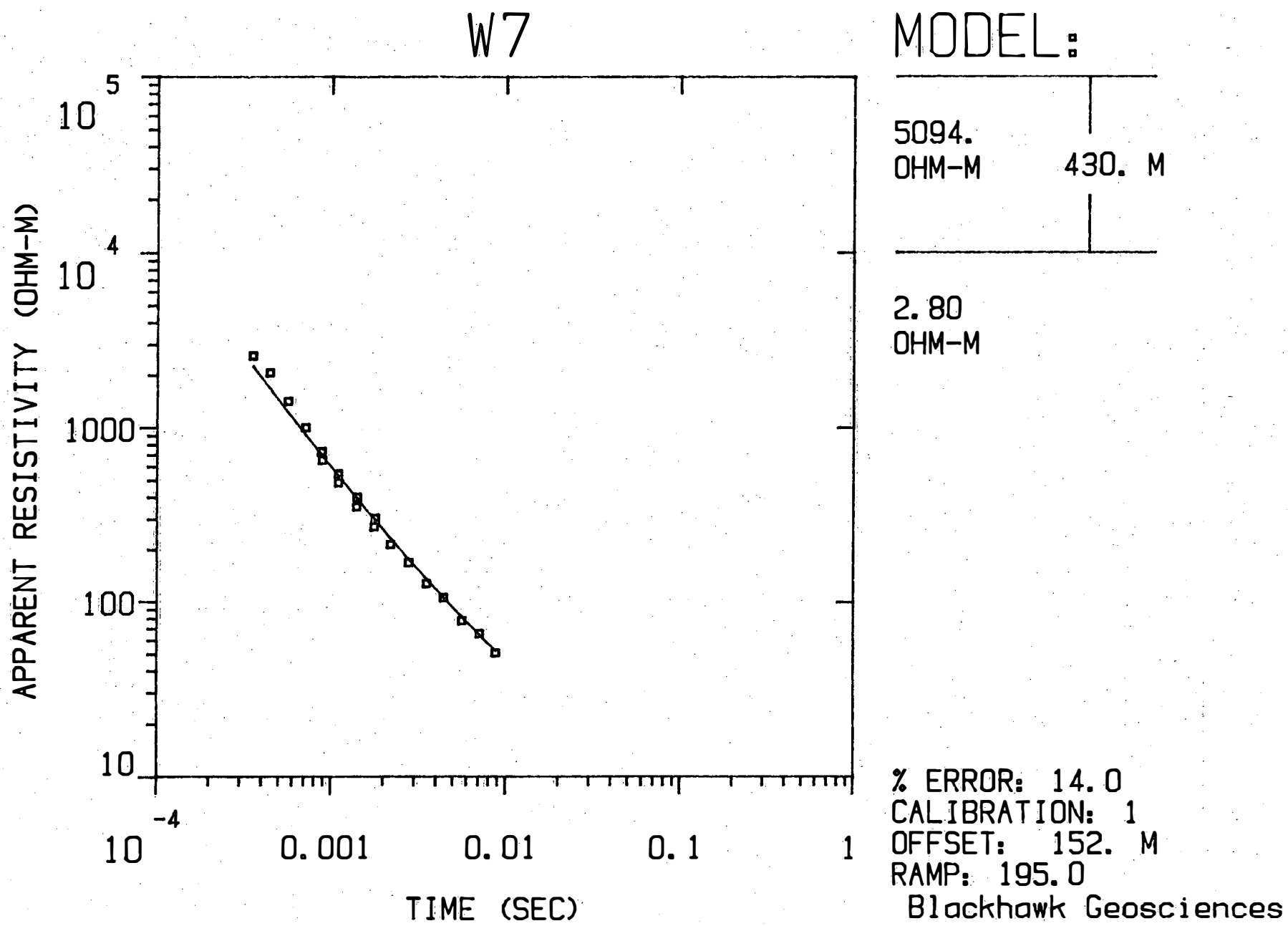
RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		365.8	1200.0		
496.39	461.8	-96.0	-314.9	0.9	0.9
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	8.00E+02	7.03E+02	13.779	
2	1.10E-03	5.73E+02	5.64E+02	1.499	
3	1.40E-03	4.17E+02	4.35E+02	-4.211	
4	1.77E-03	3.14E+02	3.31E+02	-5.187	
5	2.20E-03	2.49E+02	2.60E+02	-4.121	
6	2.80E-03	1.92E+02	1.99E+02	-3.652	
7	3.55E-03	1.43E+02	1.53E+02	-6.364	
8	4.43E-03	1.13E+02	1.21E+02	-6.793	
9	5.64E-03	9.12E+01	9.39E+01	-2.970	
10	7.13E-03	6.96E+01	7.38E+01	-5.630	
11	8.81E-03	5.88E+01	6.00E+01	-2.104	
12	1.10E-02	4.69E+01	4.87E+01	-3.611	
13	1.41E-02	4.02E+01	3.86E+01	4.218	
14	1.80E-02	3.39E+01	3.14E+01	7.997	
15	2.22E-02	2.81E+01	2.62E+01	7.567	
16	2.85E-02	2.45E+01	2.16E+01	13.579	
17	3.60E-02	2.18E+01	1.81E+01	20.154	
18	4.49E-02	1.91E+01	1.55E+01	23.177	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 18 DATA POINTS, RAMP: 195.0 MICROSEC, DATA: W6
1701 002N 006N Z OPR XTL H 5 8+100
Ch.21 = 0.195 Ch.22 = 0.089 Ch.23 = 19 Ch.24 =
RMS LOG ERROR: 5.87E-02, ANTILOG YIELDS 14.4851 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.25
F 2 0.00 0.00
T 1 0.01 0.00 1.00
P 1 F 2 T 1



MODEL:

5094.
OHM-M

430. M

2.80
OHM-M

% ERROR: 14.0
CALIBRATION: 1
OFFSET: 152. M
RAMP: 195.0

Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		338.3	1110.0		
5093.94	430.2	-91.9	-301.4	0.1	0.1
2.80					

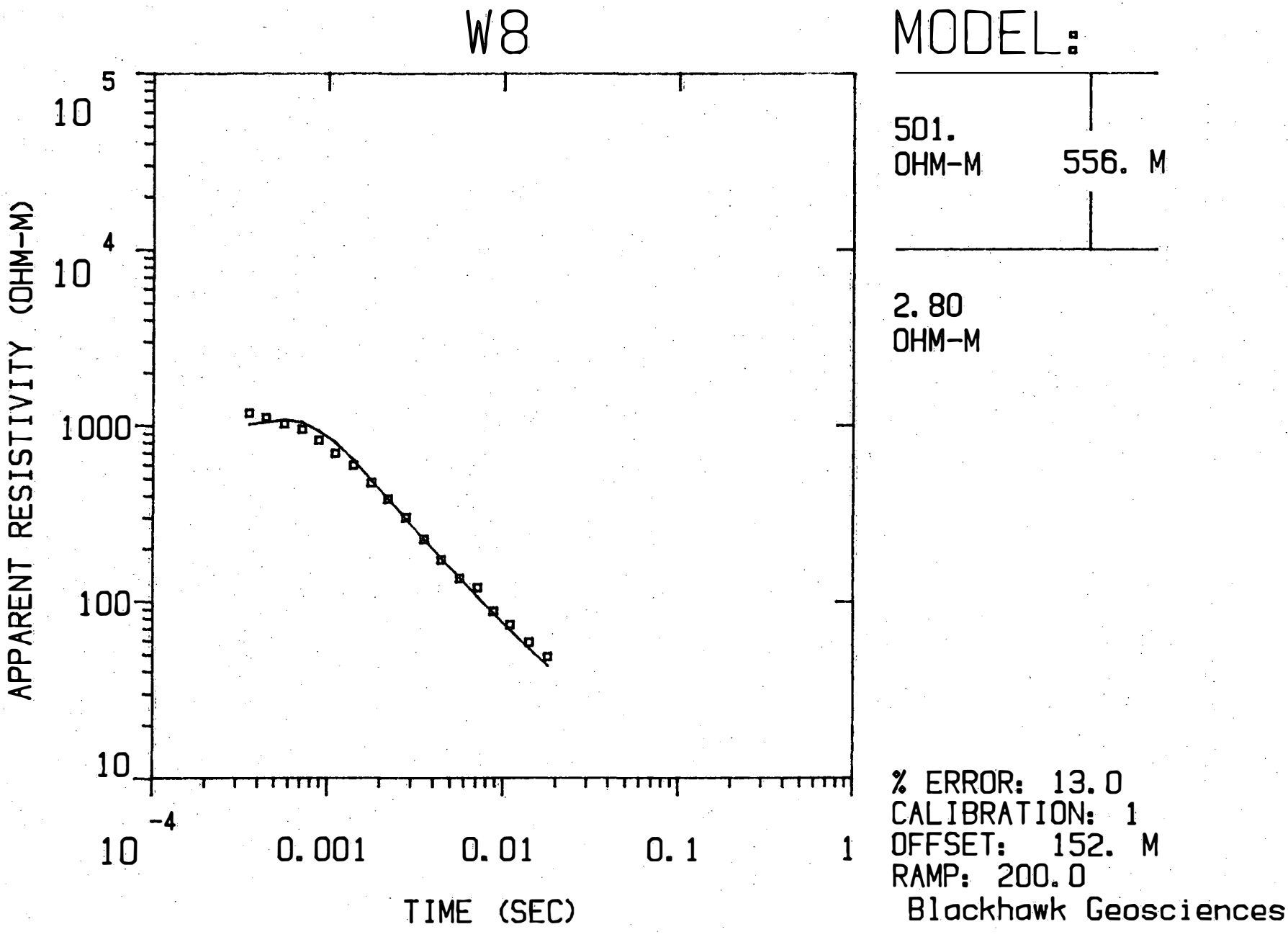
	TIMES	DATA	CALC	% ERROR	STD ERR
1	3.55E-04	2.57E+03	2.25E+03	14.190	
2	4.43E-04	2.06E+03	1.68E+03	22.063	
3	5.64E-04	1.41E+03	1.23E+03	14.073	
4	7.13E-04	9.97E+02	9.15E+02	8.971	
5	8.81E-04	7.27E+02	7.03E+02	3.484	
6	8.90E-04	6.50E+02	6.94E+02	-6.263	
7	1.10E-03	5.42E+02	5.36E+02	1.243	
8	1.10E-03	4.84E+02	5.33E+02	-9.213	
9	1.40E-03	3.51E+02	3.98E+02	-11.811	
10	1.41E-03	4.00E+02	3.95E+02	1.265	
11	1.77E-03	2.70E+02	3.01E+02	-10.349	
12	1.80E-03	3.02E+02	2.96E+02	2.012	
13	2.20E-03	2.14E+02	2.33E+02	-8.329	
14	2.80E-03	1.68E+02	1.77E+02	-5.231	
15	3.55E-03	1.27E+02	1.36E+02	-6.194	
16	4.43E-03	1.05E+02	1.07E+02	-1.102	
17	5.64E-03	7.74E+01	8.24E+01	-6.021	
18	7.13E-03	6.54E+01	6.45E+01	1.323	
19	8.81E-03	5.05E+01	5.23E+01	-3.291	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 19 DATA POINTS, RAMP: 195.0 MICROSEC, DATA: W7
1701 002N 007N Z OPR XTL H 5 8+100
Ch.21 = 0.195 Ch.22 = 0.089 Ch.23 = 19 Ch.24 =
RMS LOG ERROR: 5.69E-02, ANTILOG YIELDS 14.0020 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.19		
F 2	0.00	0.00	
T 1	0.00	0.00	1.00
	P 1	F 2	T 1



MODEL:

501.
OHM-M

556. M

2.80
OHM-M

% ERROR: 13.0
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0

Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		463.3	1520.0		
501.50	556.1	-92.8	-304.5	1.1	1.1
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	3.55E-04	1.17E+03	1.02E+03	14.951	
2	4.43E-04	1.11E+03	1.05E+03	5.421	
3	5.64E-04	1.02E+03	1.08E+03	-5.601	
4	7.13E-04	9.51E+02	1.04E+03	-8.784	
5	8.85E-04	8.22E+02	9.32E+02	-11.762	
6	1.10E-03	6.94E+02	8.04E+02	-13.726	
7	1.40E-03	5.93E+02	6.39E+02	-7.248	
8	1.77E-03	4.72E+02	4.89E+02	-3.498	
9	2.20E-03	3.83E+02	3.87E+02	-0.974	
10	2.80E-03	3.00E+02	2.96E+02	1.578	
11	3.55E-03	2.26E+02	2.26E+02	-0.138	
12	4.43E-03	1.72E+02	1.77E+02	-2.873	
13	5.64E-03	1.35E+02	1.37E+02	-1.557	
14	7.13E-03	1.20E+02	1.07E+02	12.185	
15	8.81E-03	8.79E+01	8.59E+01	2.338	
16	1.10E-02	7.37E+01	6.89E+01	6.983	
17	1.41E-02	5.85E+01	5.39E+01	8.631	
18	1.80E-02	4.85E+01	4.31E+01	12.406	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 18 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: W8
NEAR WAIKOLOA ROAD BETWEEN
LOOP 14 AND 15
RMS LOG ERROR: 5.29E-02, ANTILOG YIELDS 12.9505 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.11		
F 2	0.00	0.00	
T 1	-0.01	0.00	0.47
	P 1	F 2	T 1

WEST HAWAII UTILITIES
Post Office Box 384809
Waikoloa, Hawaii 96738

Tel: (808) 883-9355
Fax: (808) 883-9768

TO: TOM NANCE **FROM:** Stephen Green

TOM NANCE WATER RESOURCES ENGINEERING

FAX: 808.538.7757 **PAGES:** 13

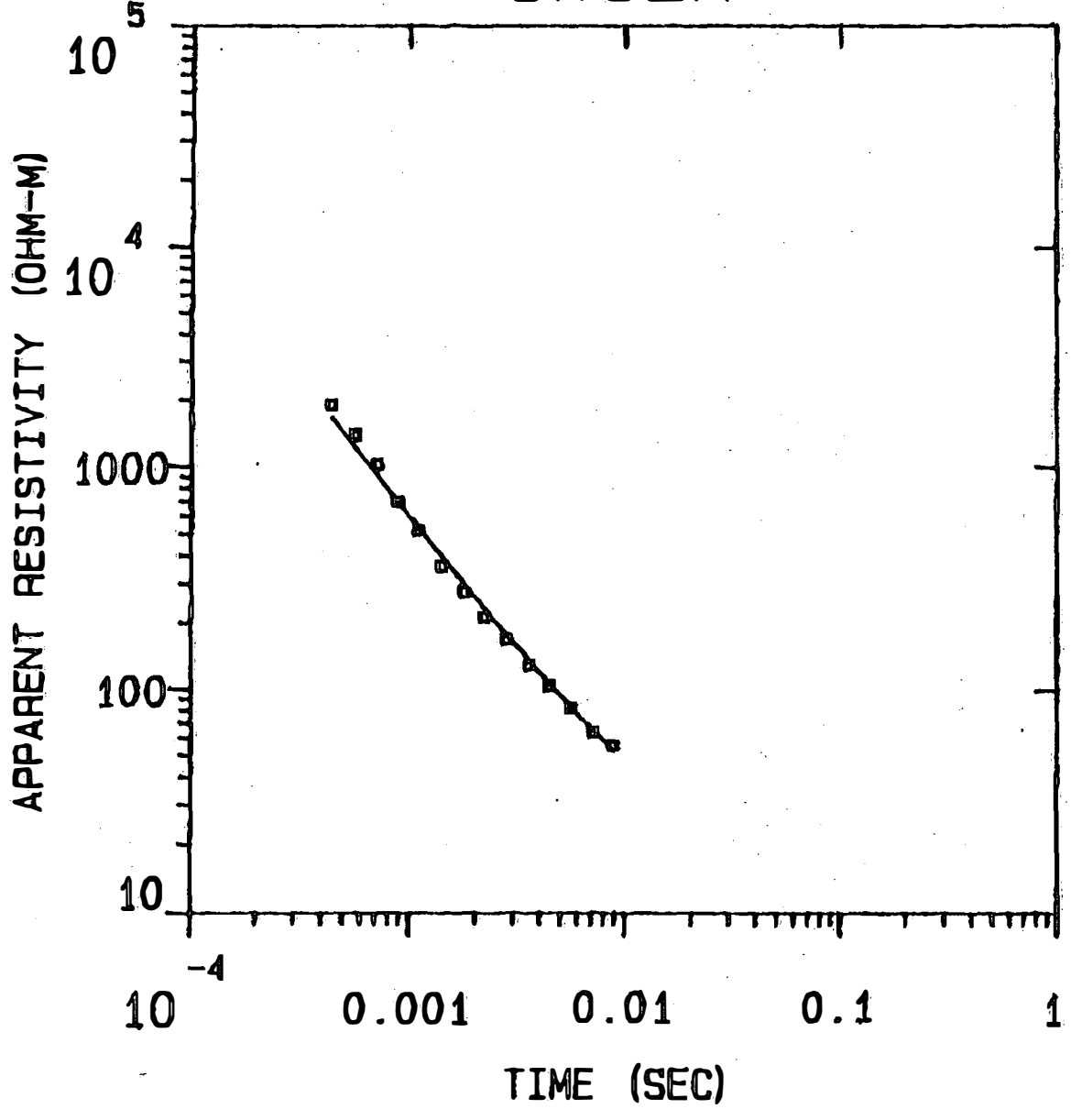
RE: GTC 1988 DRAFT WAIKOLOA LANDS GROUNDWATER STUDY **DATE:** 8/8/03

TOM,

ATTACHED ARE SOUNDINGS 12, 13, 14, 33, 34, & 35 FROM THE GTC REPORT AS REQUESTED.

1988

1W12N



MODEL:

3320.
OHM-M

429. M

2.80
OHM-M

% ERROR: 12.0
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
INTERPEX: ARATI

1W12N

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
3320.26	429.1	359.7	1180.0	0.1	0.1
2.80		-69.4	-227.9		

	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	1.89E+03	1.66E+03	13.750	
2	5.64E-04	1.39E+03	1.22E+03	13.685	
3	7.13E-04	1.02E+03	9.08E+02	12.012	
4	8.85E-04	6.97E+02	6.92E+02	0.687	
5	1.10E-03	5.18E+02	5.31E+02	-2.484	
6	1.40E-03	3.59E+02	3.96E+02	-9.413	
7	1.77E-03	2.76E+02	2.99E+02	-7.924	
8	2.20E-03	2.13E+02	2.33E+02	-8.418	
9	2.80E-03	1.69E+02	1.77E+02	-4.237	
10	3.55E-03	1.29E+02	1.35E+02	-4.738	
11	4.43E-03	1.04E+02	1.07E+02	-2.477	
12	5.64E-03	8.22E+01	8.25E+01	-0.315	
13	7.13E-03	6.41E+01	6.50E+01	-1.439	
14	8.81E-03	5.59E+01	5.27E+01	5.949	

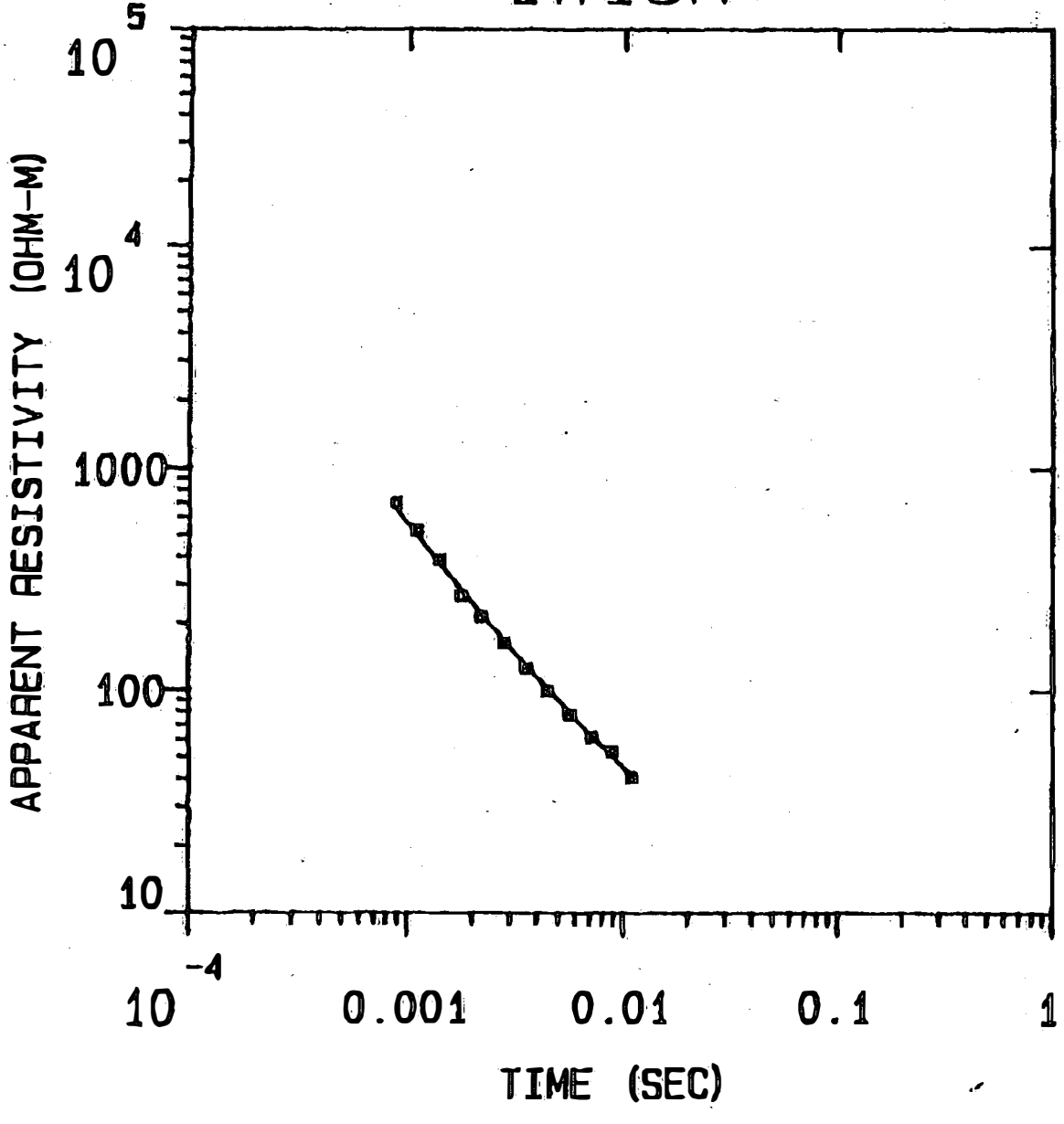
R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 14 DATA POINTS. RAMP: 200.0 MICROSEC. DATA: 1W12N
WAIKOLOA
1000 FT LOOP
RMS LOG ERROR: 4.90E-02. ANTILOG YIELDS 11.9541 %
LATE TIME PARAMETERS

* BLACKHAWK GEOSCIENCES, INC. *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.04		
F 2	0.00	0.00	
T 1	0.01	0.00	1.00
	P 1	F 2	T 1

1W13N



MODEL:

3115.
OHM-M

419. M

2.80
OHM-M

% ERROR: 5.54
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
INTERPEX: ARRTI

1W13N

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		353.6	1160.0		
3115.24	418.8	-65.2	-213.9	0.1	0.1
2.80					

	TIME	DATA	CALC	% ERROR	STD ERR
1	8.85E-04	7.01E+02	6.55E+02	7.068	
2	1.10E-03	5.23E+02	5.02E+02	4.093	
3	1.41E-03	3.86E+02	3.73E+02	3.499	
4	1.77E-03	2.68E+02	2.84E+02	-5.535	
5	2.20E-03	2.14E+02	2.21E+02	-2.800	
6	2.80E-03	1.65E+02	1.68E+02	-1.979	
7	3.55E-03	1.26E+02	1.29E+02	-2.379	
8	4.43E-03	9.91E+01	1.02E+02	-2.381	
9	5.64E-03	7.75E+01	7.87E+01	-1.546	
10	7.13E-03	6.18E+01	6.20E+01	-0.403	
11	8.81E-03	5.29E+01	5.05E+01	4.771	
12	1.10E-02	4.08E+01	4.09E+01	-0.375	

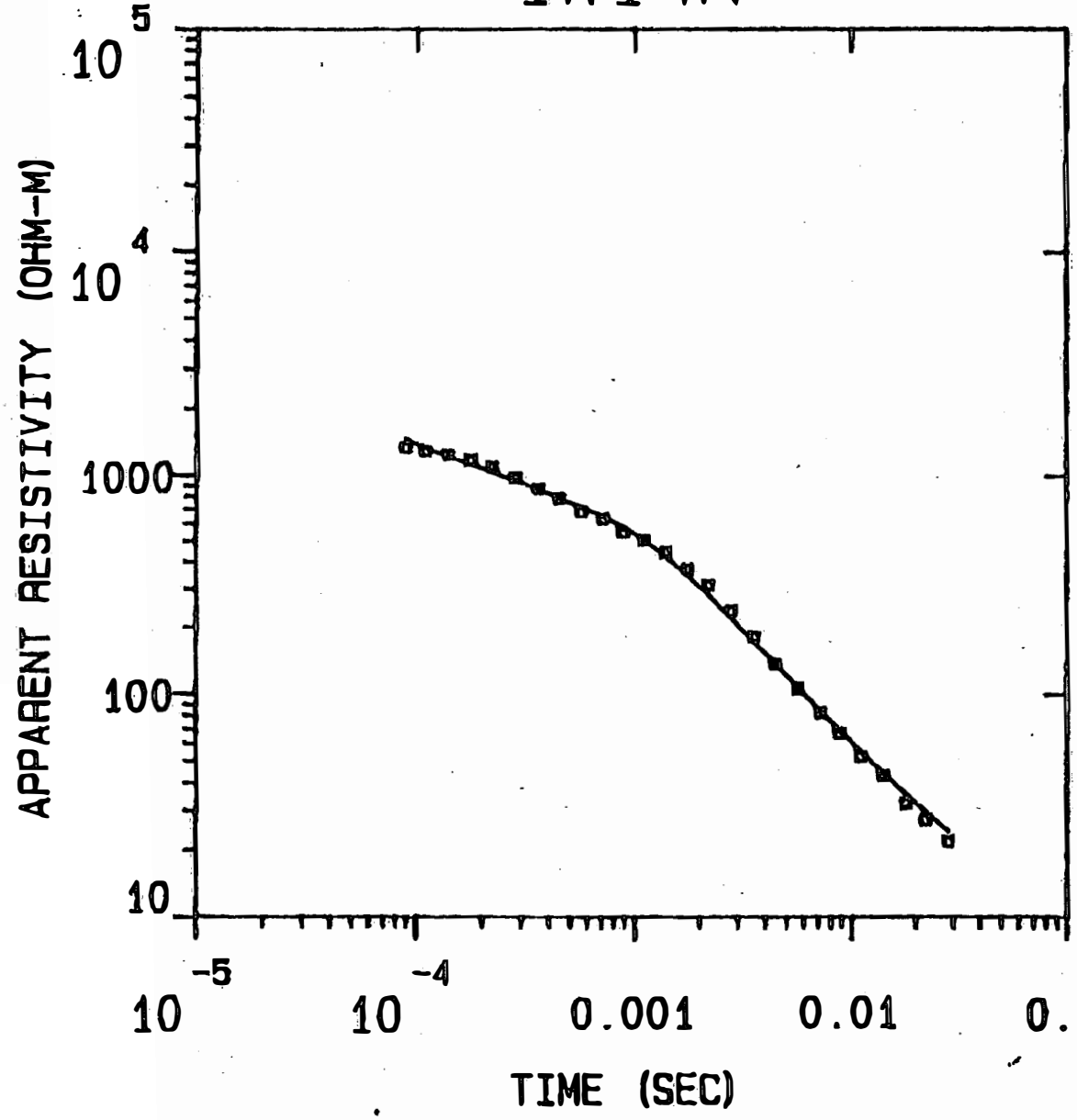
R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY. 12 DATA POINTS, RAMP: 200.0 MICROSEC. DATA: 1W13N
WAIKOLOA
1000 FT LOOP
RMS LOG ERROR: 2.34E-02, ANTILOG YIELDS 5.5408 %
LATE TIME PARAMETERS

* BLACKHAWK GEOSCIENCES, INC. *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.16		
F 2	0.00	0.00	
T 1	-0.01	0.00	1.00
	P 1	F 2	T 1

1W14N



MODEL:

497.
OHM-M

392. M

33.6
OHM-M

117. M

2.80
OHM-M

% ERROR: 8.91
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
INTERPEX: ARRTI

1W14N

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		426.7	1400.0		
496.97	391.6	35.1	115.1	0.8	0.8
33.56	117.1	-82.0	-269.0	3.5	4.3
2.80					

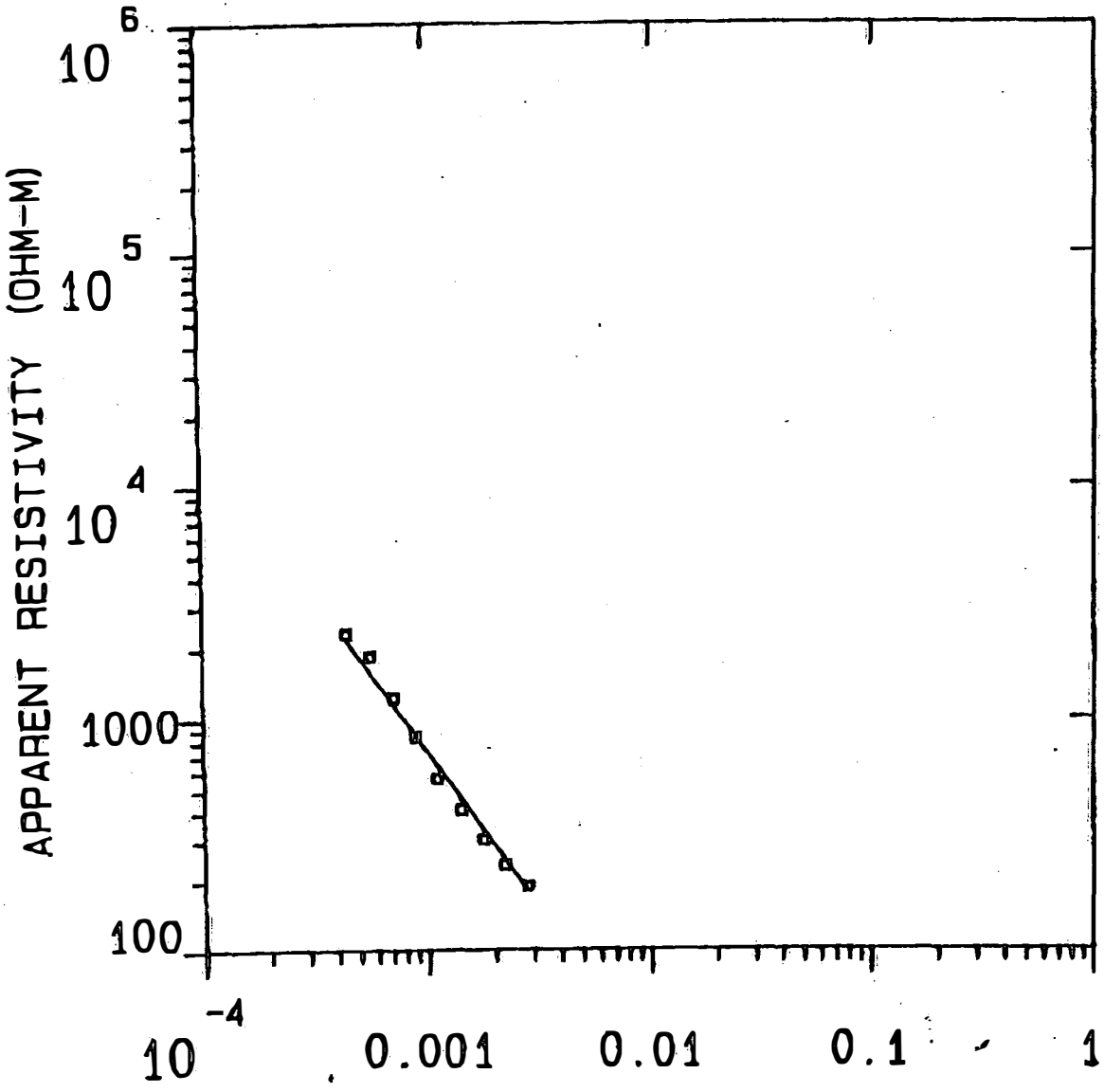
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.34E+03	1.47E+03	-8.499	
2	1.10E-04	1.29E+03	1.34E+03	-3.414	
3	1.40E-04	1.24E+03	1.22E+03	2.065	
4	1.77E-04	1.17E+03	1.12E+03	4.872	
5	2.20E-04	1.10E+03	1.04E+03	5.753	
6	2.80E-04	9.84E+02	9.50E+02	3.493	
7	3.55E-04	8.72E+02	8.68E+02	0.457	
8	4.43E-04	7.83E+02	7.89E+02	-0.866	
9	5.64E-04	6.81E+02	7.13E+02	-4.536	
10	7.13E-04	6.33E+02	6.50E+02	-2.651	
11	8.85E-04	5.49E+02	5.84E+02	-5.988	
12	1.10E-03	5.09E+02	5.10E+02	-0.300	
13	1.40E-03	4.48E+02	4.24E+02	5.599	
14	1.77E-03	3.74E+02	3.46E+02	8.009	
15	2.20E-03	3.14E+02	2.80E+02	12.273	
16	2.80E-03	2.40E+02	2.19E+02	9.347	
17	3.55E-03	1.82E+02	1.71E+02	6.106	
18	4.43E-03	1.37E+02	1.36E+02	0.091	
19	5.64E-03	1.07E+02	1.07E+02	-0.163	
20	7.13E-03	8.26E+01	8.41E+01	-1.773	
21	8.81E-03	6.67E+01	6.84E+01	-2.445	
22	1.10E-02	5.27E+01	5.55E+01	-5.072	
23	1.41E-02	4.32E+01	4.39E+01	-1.472	
24	1.80E-02	3.24E+01	3.55E+01	-8.650	
25	2.22E-02	2.74E+01	2.95E+01	-7.057	
26	2.85E-02	2.19E+01	2.42E+01	-9.530	

R: 152. X: 0. Y: 152. DL: 305. RLO: 169. CF: 1.0000
TDHZ ARRAY. 26 DATA POINTS. RAMP: 200.0 MICROSEC. DATA: 1W14N
WAIKOLOA
1000 FT LOOP
RMS LOG ERROR: 3.71E-02. ANTILOG YIELD: 8.0058 %
LATE TIME PARAMETER:

- BLACKHAWK GEOSCIENCES, INC. -

PARAMETER RESOLUTION MATRIX:
"A" MULTI-LAYER PARAMETER
P 1 0.1
P 2 [illegible] 0.11
P 3 [illegible] 0.00 0.00

1W33NA



MODEL:

42088.
OHM-M

501. M

2.80
OHM-M

% ERROR: 15.5
CALIBRATION: 1
OFFSET: 152. M
RAMP: 160.0

1W33NA

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		378.0	1240.0		
42088.40	501.3	-123.4	-404.8	0.0	0.0
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	2.31E+03	2.17E+03	6.780	
2	5.64E-04	1.85E+03	1.56E+03	18.492	
3	7.13E-04	1.23E+03	1.13E+03	8.879	
4	8.85E-04	8.38E+02	8.42E+02	-0.498	
5	1.10E-03	5.55E+02	6.30E+02	-11.888	
6	1.40E-03	4.09E+02	4.56E+02	-10.439	
7	1.77E-03	3.04E+02	3.34E+02	-9.129	
8	2.20E-03	2.36E+02	2.49E+02	-5.136	
9	2.80E-03	1.89E+02	1.80E+02	5.368	

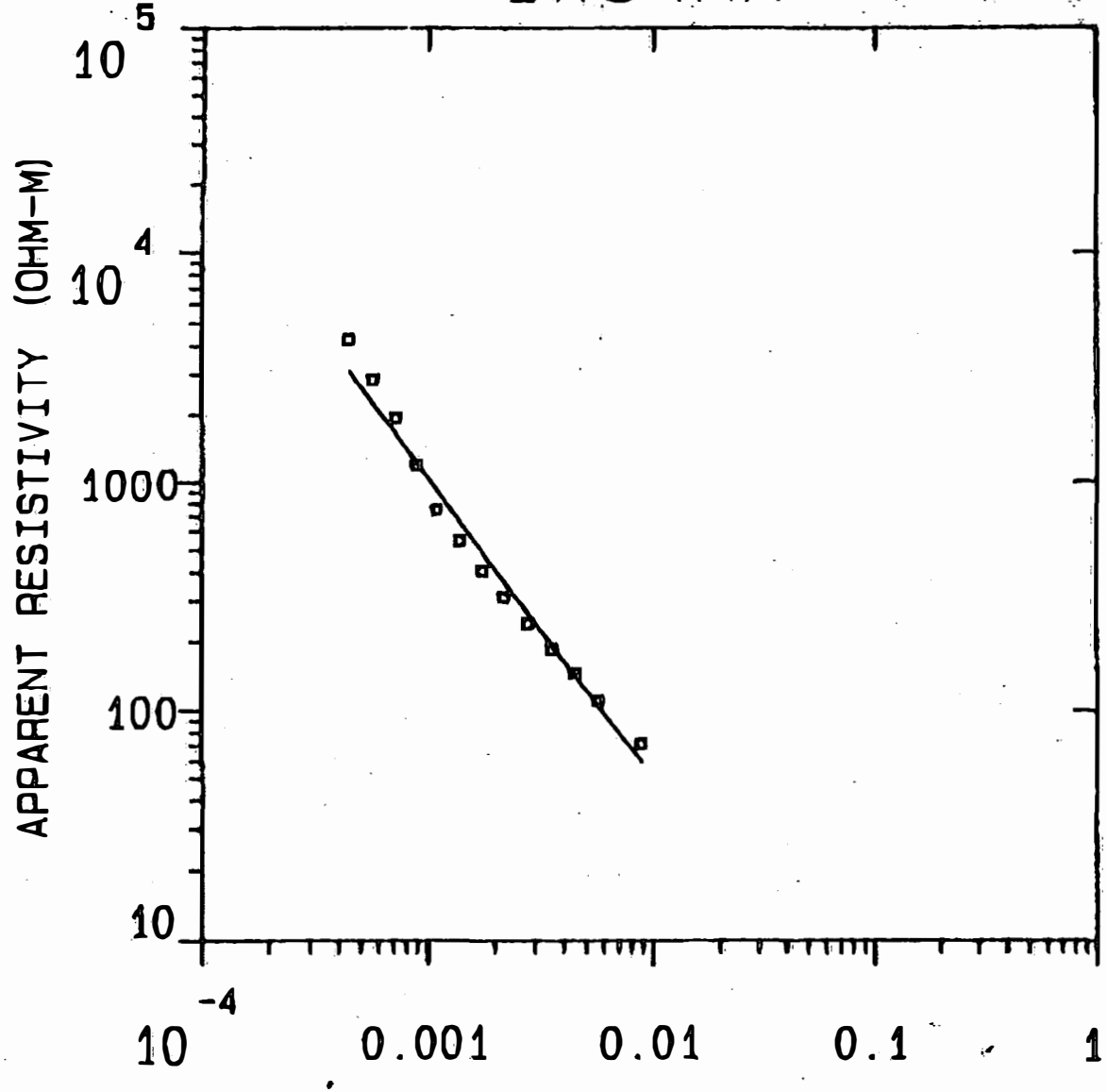
R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY. 9 DATA POINTS. RAMP: 160.0 MICROSEC. DATA: 1W33NA
WAIKOLOA
1000 FOOT LOOP
RMS LOG ERROR: 6.26E-02. ANTILOG YIELDS 15.5147 %
LATE TIME PARAMETERS

* BLACKHAWK GEOSCIENCES, INC. *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	F 2	T 1
P 1	0.00		
F 2	0.00	0.00	
T 1	0.00	0.00	0.98

1W34NA



MODEL:

28594. OHM-M

574. M

2.80 OHM-M

% ERROR: 28.5
CALIBRATION: 1
OFFSET: 152. M
RAMP: 160.0

1W34NA

2 LAYERS

	TIVITY THICKNESS (OHM-M) (M)	ELEVATION (M)	(FEET)	CONDUCTANCE (S) LAYER	TOTAL
		411.5	1350.0		
	574.2	-162.7	-533.7	0.0	0.0

	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	4.26E+03	3.09E+03	37.890	
2	5.64E-04	2.85E+03	2.23E+03	27.864	
3	7.13E-04	1.93E+03	1.63E+03	18.491	
4	8.85E-04	1.19E+03	1.22E+03	-2.505	
5	1.10E-03	7.49E+02	9.08E+02	-17.450	
6	1.40E-03	5.46E+02	6.57E+02	-16.973	
7	1.77E-03	4.07E+02	4.82E+02	-15.655	
8	2.20E-03	3.12E+02	3.62E+02	-13.720	
9	2.80E-03	2.39E+02	2.63E+02	-9.254	
10	3.55E-03	1.86E+02	1.92E+02	-3.084	
11	4.43E-03	1.46E+02	1.42E+02	2.275	
12	5.64E-03	1.10E+02	1.04E+02	5.478	
13	8.81E-03	7.16E+01	5.93E+01	20.703	

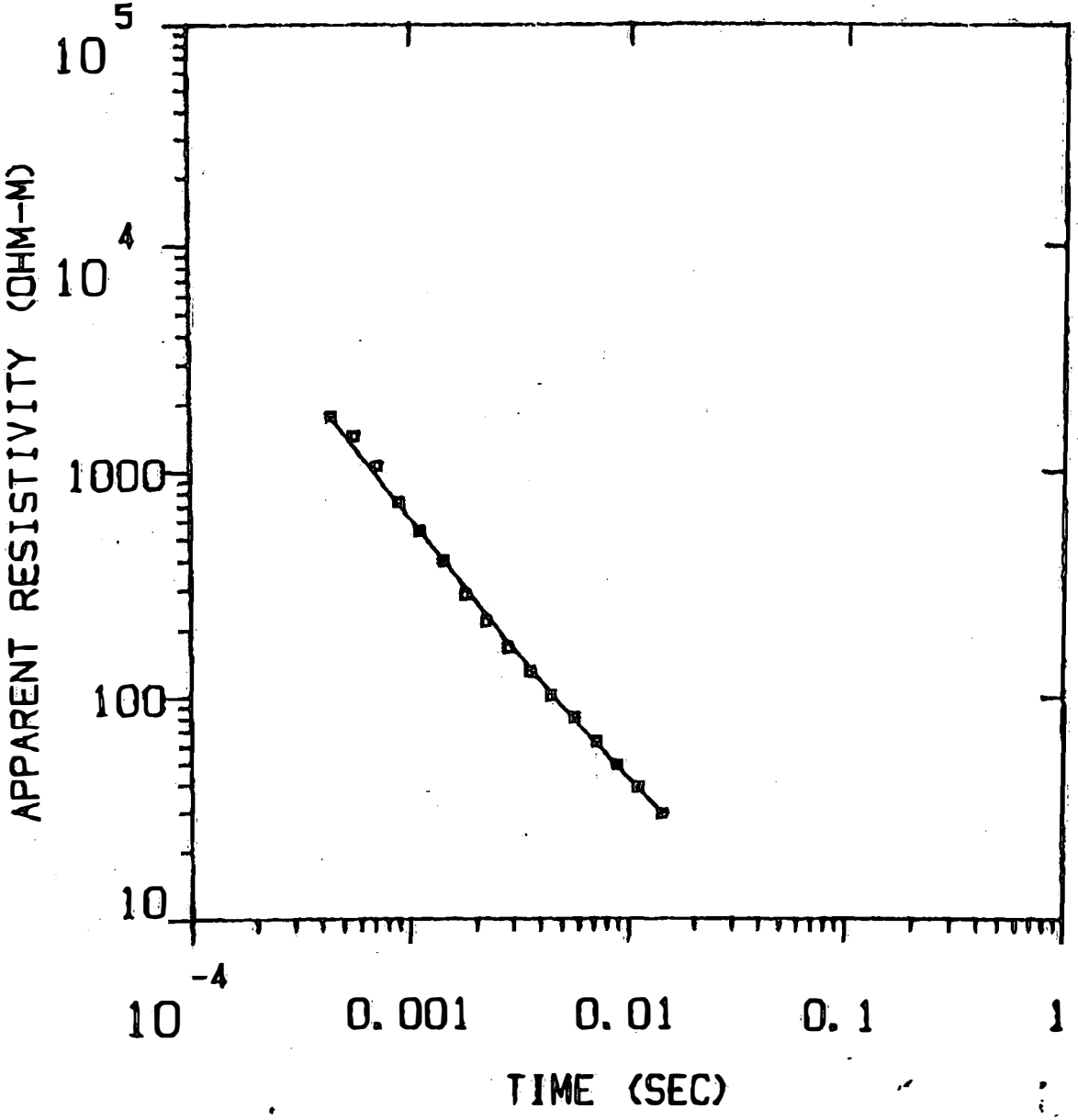
A: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 13 DATA POINTS, RAMP: 160.0 MICROSEC. DATA: 1W34NA
WAIKOLOA
1000 FOOT LOOP
RMS LOG ERROR: 1.09E-01, ANTILOG YIELDS 28.5474 %
LATE TIME PARAMETERS

* BLACKHAWK GEOSCIENCES, INC. *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

F 1	0.34		
F 2	0.00	0.00	
T 1	-0.14	0.00	0.95
	P 1	F 2	T 1

1W35NRC



MODEL:

12038. OHM-M

438. M

2.80 OHM-M

% ERROR: 8.18
CALIBRATION: 1
OFFSET: 152. M
RAMP: 170.0
INTERPEX: ARRTI

1W35NRC

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		378.0	1240.0		
12038.08	437.7	-59.8	-196.1	0.0	0.0
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	4.43E-04	1.74E+03	1.73E+03	0.419	
2	5.64E-04	1.42E+03	1.27E+03	12.307	
3	7.13E-04	1.05E+03	9.38E+02	11.593	
4	8.85E-04	7.23E+02	7.12E+02	1.582	
5	1.10E-03	5.38E+02	5.45E+02	-1.251	
6	1.41E-03	3.97E+02	4.02E+02	-1.332	
7	1.77E-03	2.83E+02	3.04E+02	-7.007	
8	2.20E-03	2.17E+02	2.35E+02	-7.494	
9	2.80E-03	1.66E+02	1.76E+02	-5.592	
10	3.55E-03	1.29E+02	1.34E+02	-3.436	
11	4.43E-03	1.00E+02	1.04E+02	-3.541	
12	5.64E-03	8.04E+01	7.94E+01	1.275	
13	7.13E-03	6.25E+01	6.13E+01	1.969	
14	8.81E-03	4.88E+01	4.85E+01	0.625	
15	1.10E-02	3.84E+01	3.82E+01	0.542	
16	1.41E-02	2.92E+01	2.93E+01	-0.518	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY. 16 DATA POINTS, RAMP: 170.0 MICROSEC, DATA: 1W35NRC
WAIKALOA RANCH
1000 FOOT LOOP RECALC
RMS LOG ERROR: 3.41E-02. ANTILOG YIELDS 8.1761 %
LATE TIME PARAMETERS

* BLACKHAWK GEOSCIENCES. INC. *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.00
F 2 0.00 0.00
T 1 0.00 0.00 0.98
P 1 F 2 T 1